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Case Study Examples Illustrating Modeling of PV for Distribution Planning and Analysis

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Workshop on Achieving High Penetrations of PV

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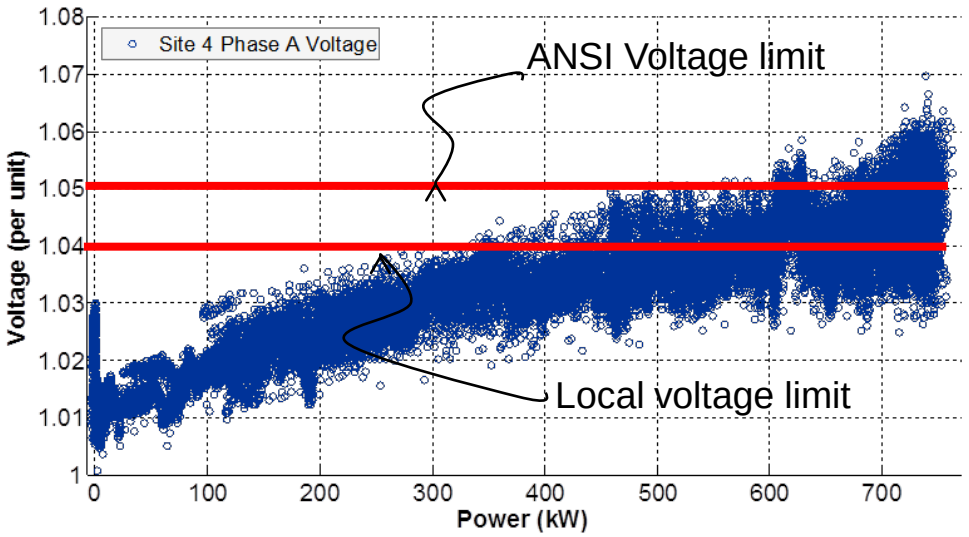
Industry Emphasis on Modeling – Why?

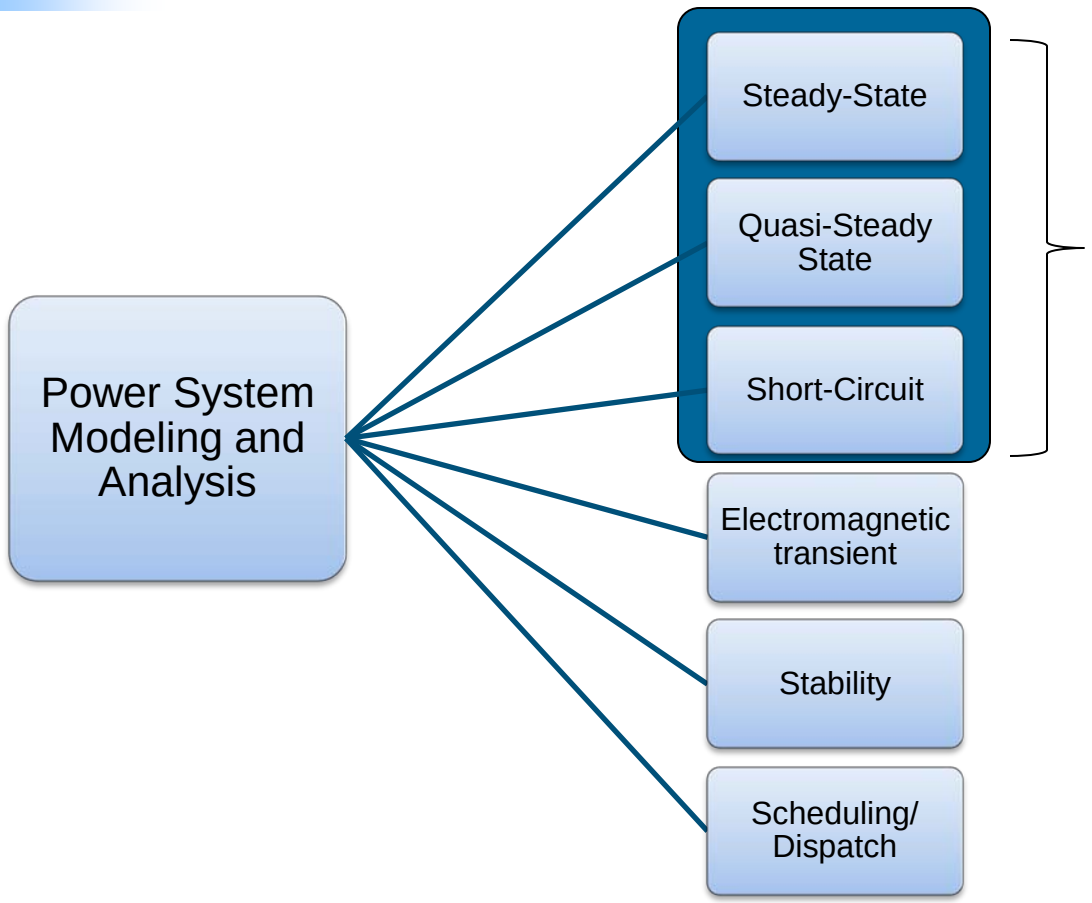
- Rapid-deployment of PV
- Higher penetration levels than ever before
- Utilities need to have a handle on potential PV impacts prior to interconnection
- Much easier to resolve potential issues before penetration levels exceed allowable limits
- Modeling enables the distribution planner to investigate solutions and “work arounds”

Example of an Existing PV System Causing Unacceptable Voltages
Measured Overvoltage Resulting from PV



Increasing PV Output →

Right Tool for the Job



Distributed PV Interconnection Analysis

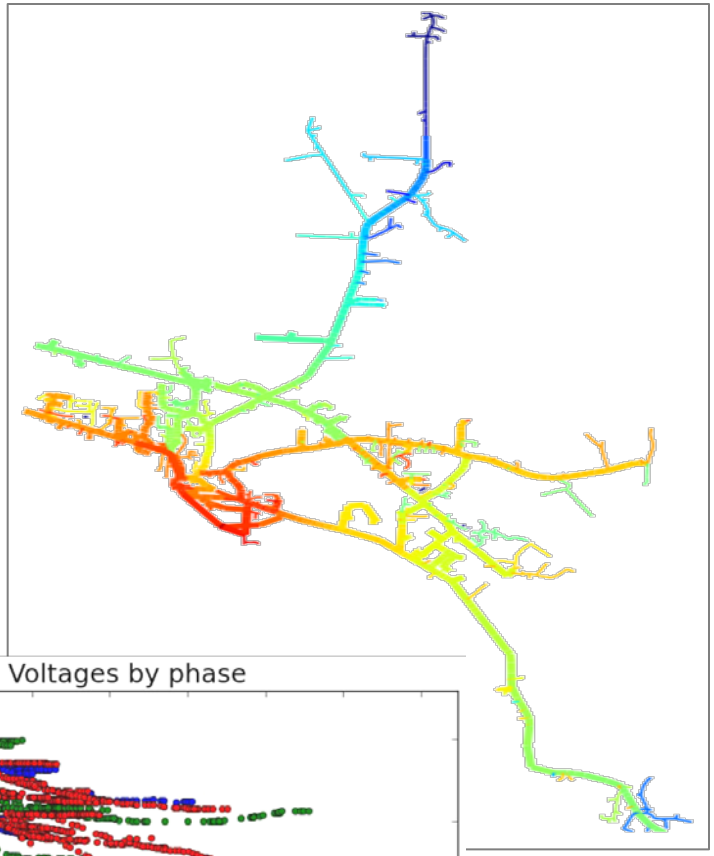
Modeling is only as good as the tool used, and the data that goes into it

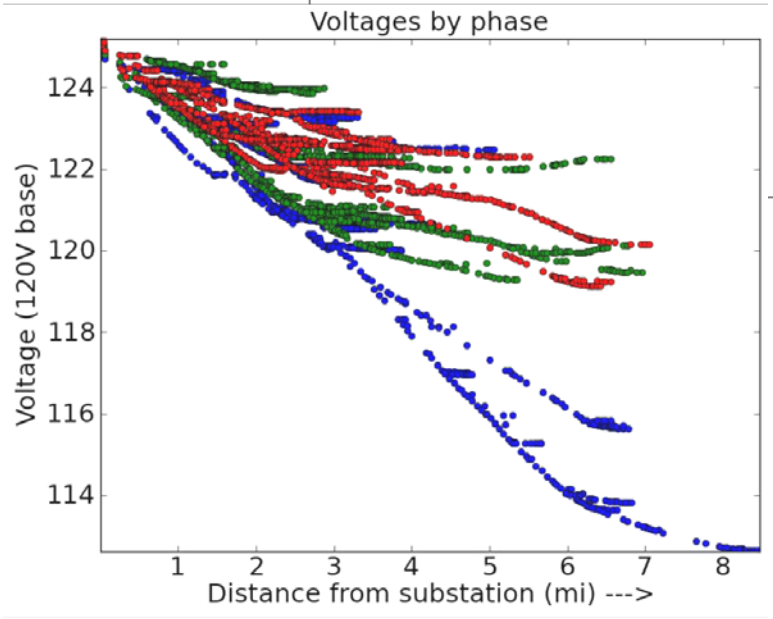
Feeder Modeling

Power Delivery
- Substation transformer
- Primary conductors
- Service transformers
- Customer service drops

Power Conversion
- Residential loads
- Commercial loads
- Existing PV systems

Power Control
- Capacitors
- Substation LTC
- Line regulators



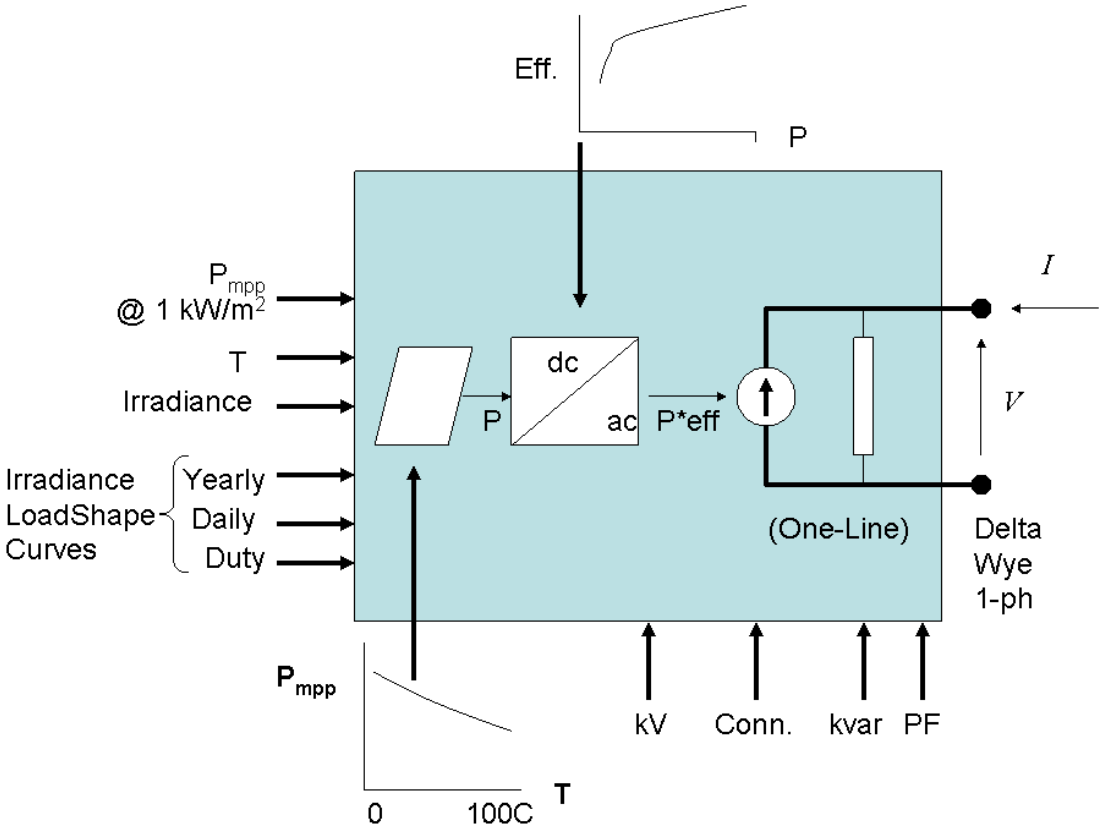


Solar PV Modeling

OpenDSS PV Model

Allows for simulation of wide range of feeder impacts

- Steady-state load flow
  - Voltage regulation
  - Thermal loading
- Time series load flow
  - Interaction with regulation controls
- Short-circuit response
  - Increased fault duty
- Harmonics
  - THD calculations



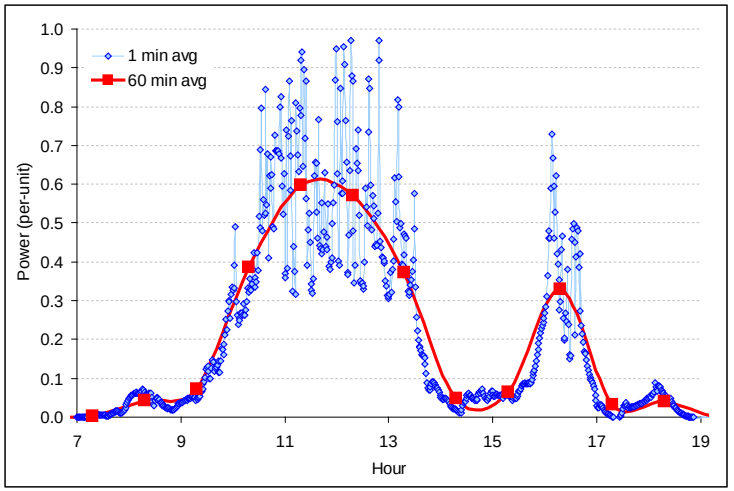
Solar Resource Modeling - Variability

- Essential to capture time-varying nature of the solar PV
  - 15 minute - Hourly – energy related concerns such as peak demand, loading, overvoltage
  - < 1 minute – voltage fluctuations, regulation control interaction
- Factors that contribute to variability
  - Size and layout of the solar facility
  - Local weather patterns
  - Centralized vs distributed
- Possible sources of data:
  - Location-specific measurement data
  - Proxy data from other PV systems
  - Mesoscale/satellite based models – typically 30 minute - hourly interval

PV data "driving" the simulation must be sampled faster than the metric and/or control interaction being simulated

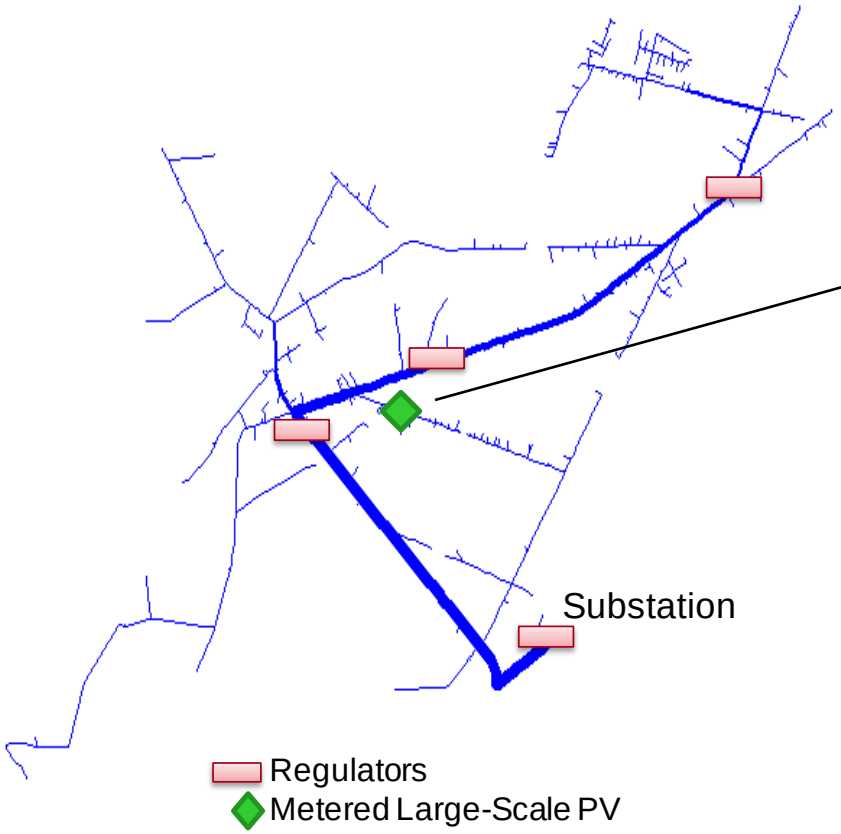
Example Ramp Rates from Existing PV

Solar Plant Size	Ramping (0-100%)
60 kW	< 10 seconds
800 kW	< 1 minute
6.5 MW	1.5-2 minutes
Feeder-wide	5-10 minutes

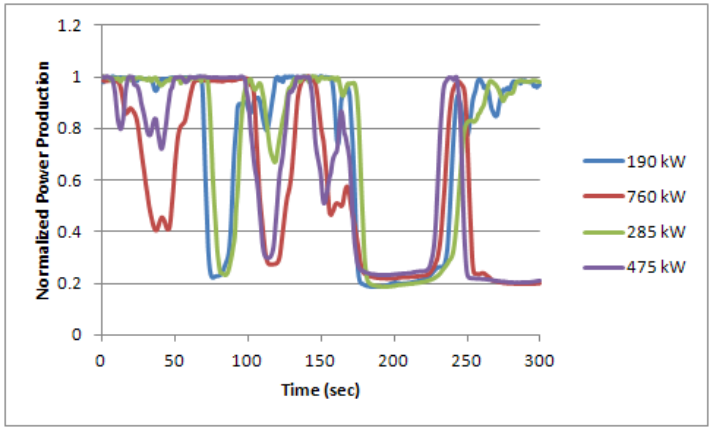


Feeder and PV Model Validation

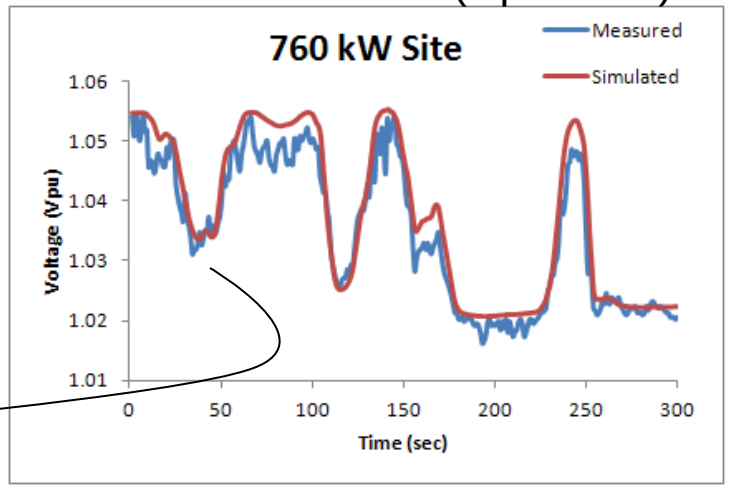
OpenDSS Feeder and PV Model Validated Against Field Data



Measured PV Production



Field vs Simulated (OpenDSS)

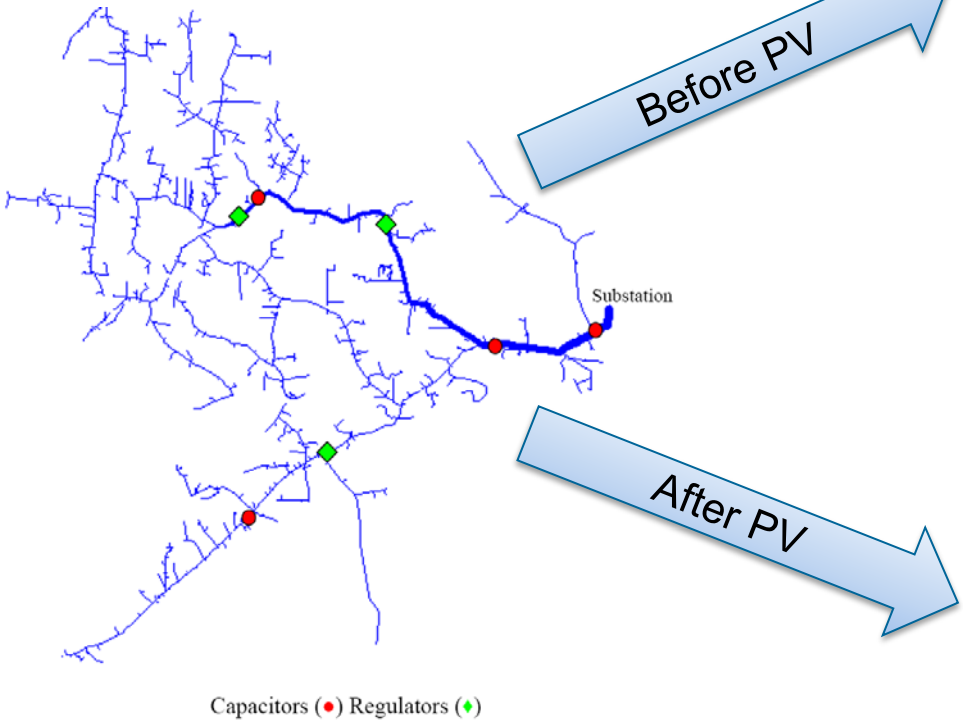


Small variations in voltage due to load fluctuations

Basic Analysis – Voltage Change Test

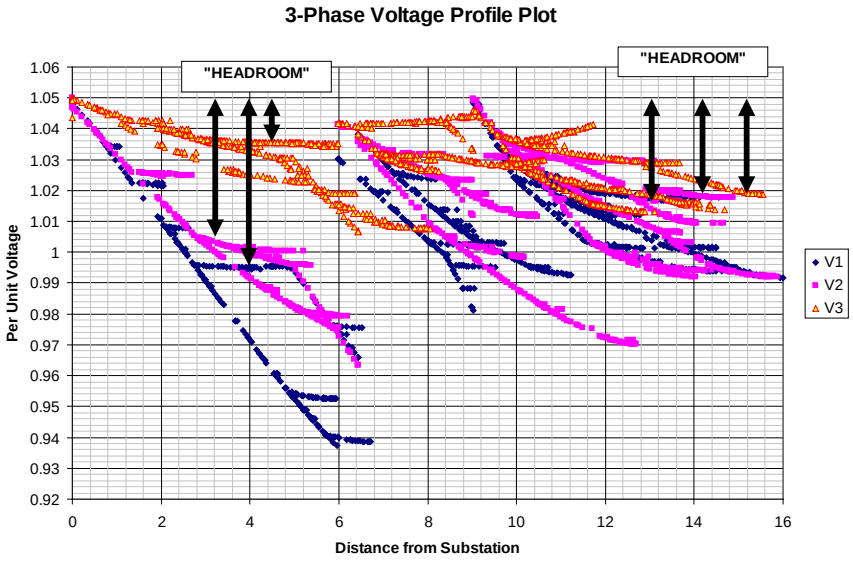
Static Load Flow
- solve load flow
- lock all controls
- add generation
- resolve

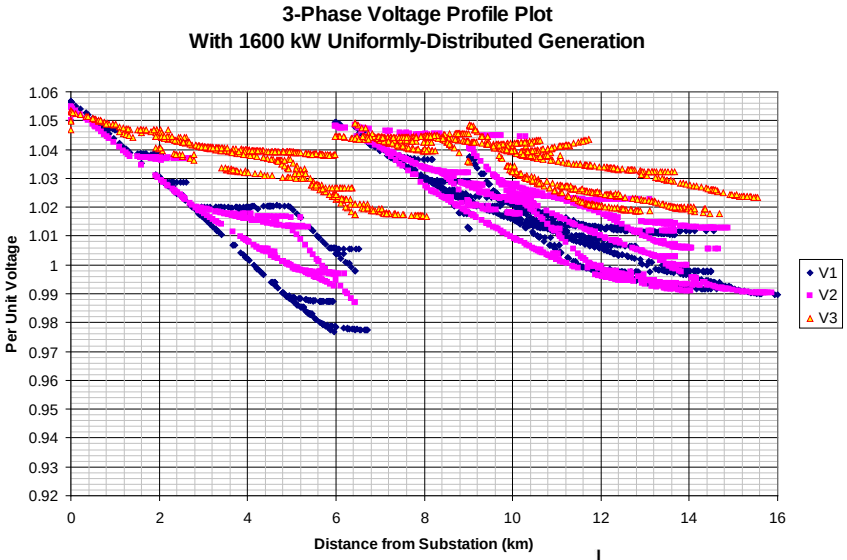
Considers Maximum Range of PV Output



Before PV

After PV





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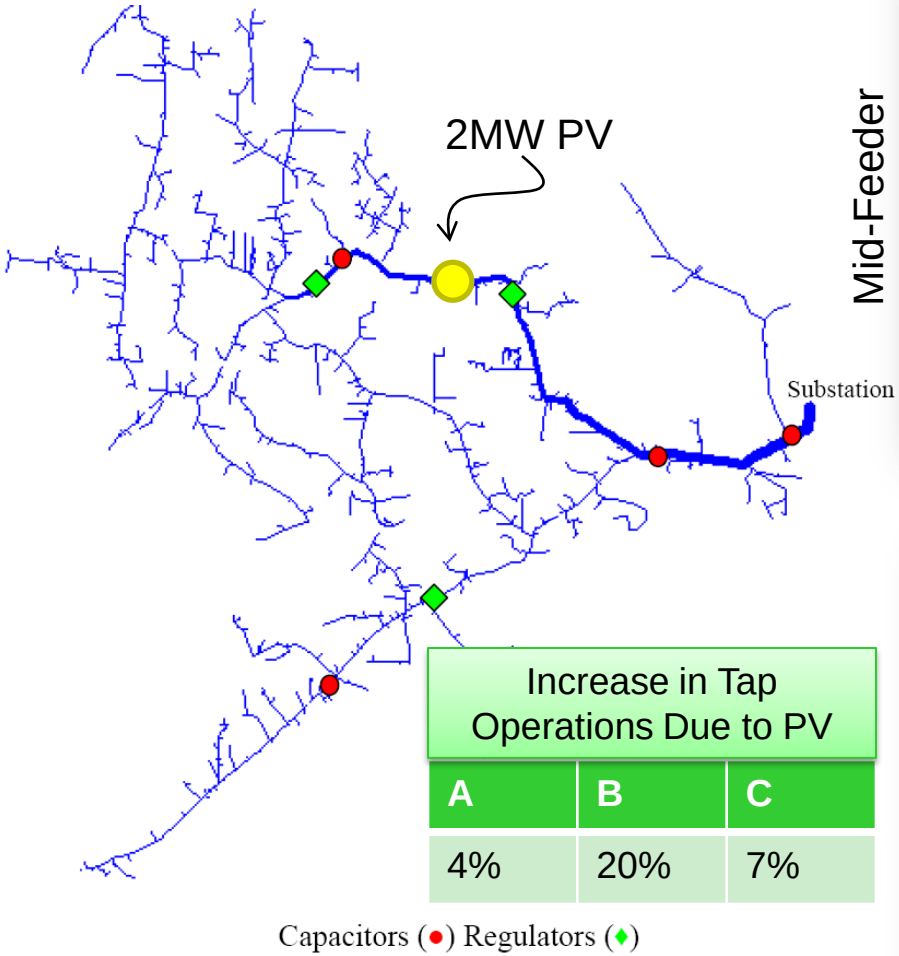
Advanced Analysis – Time Series

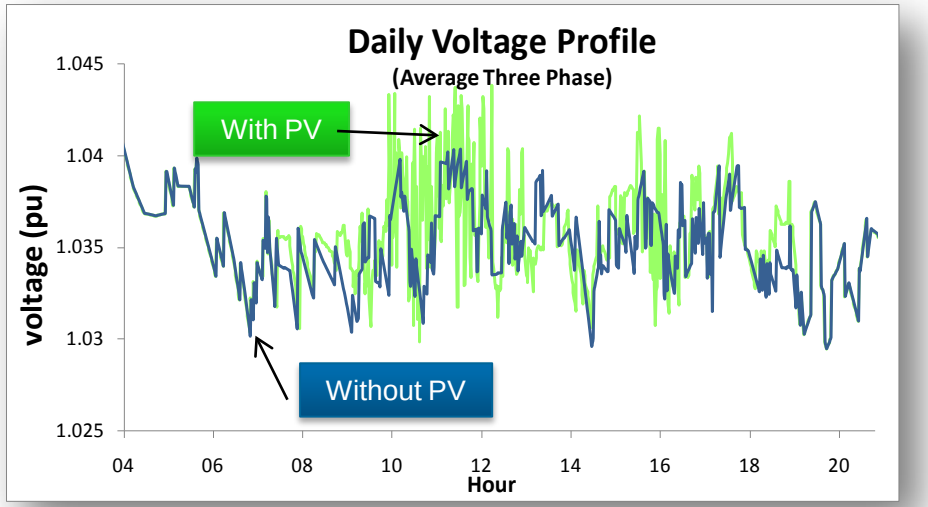
Quasi-Dynamic, Quasi-Static, etc

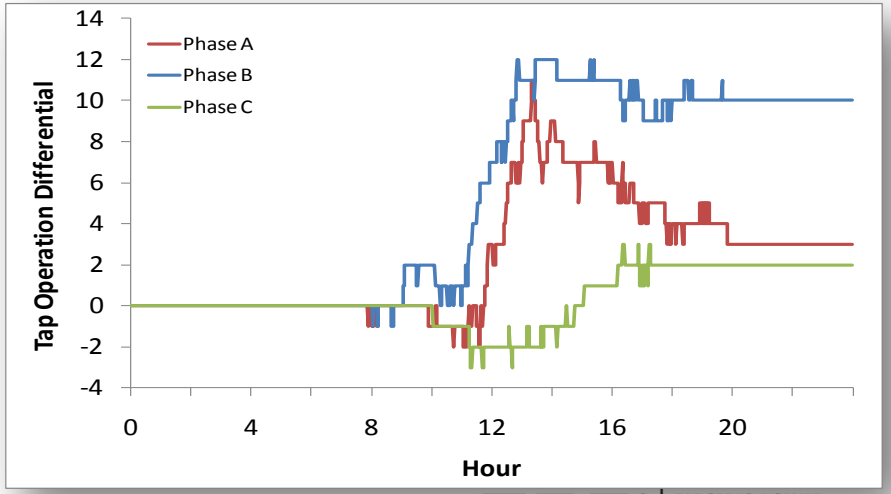
2MW PV System located Mid-Feeder Causing Increased Regulator Operation



Increase in Tap Operations Due to PV		
A	B	C
4%	20%	7%

IEEE 8500 Node Test Case





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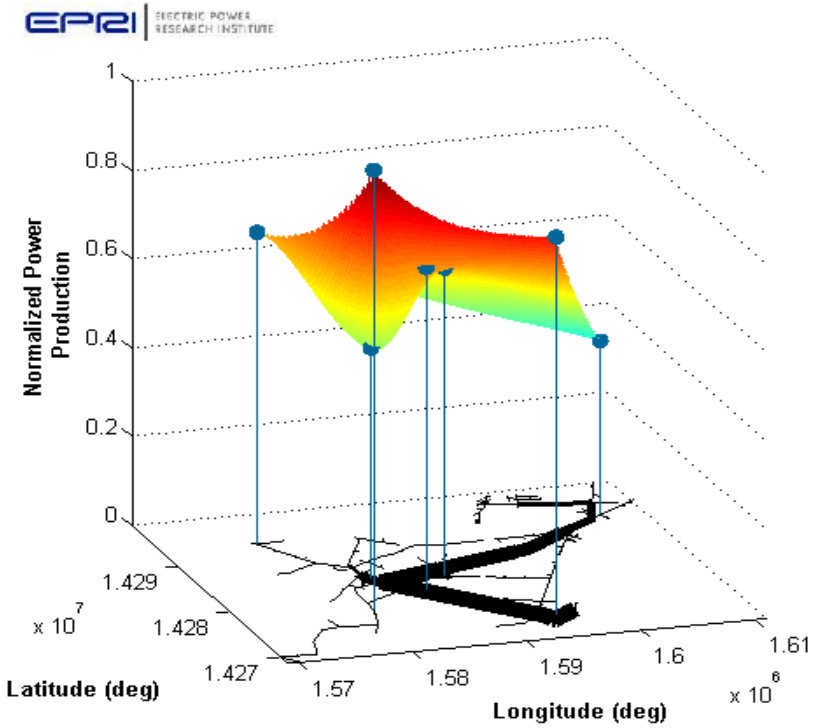
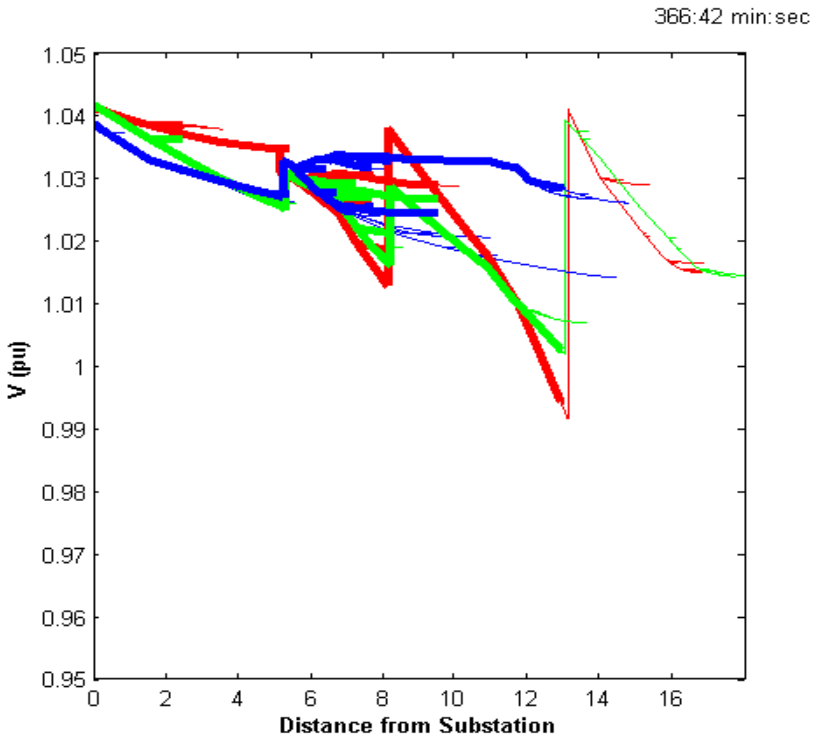
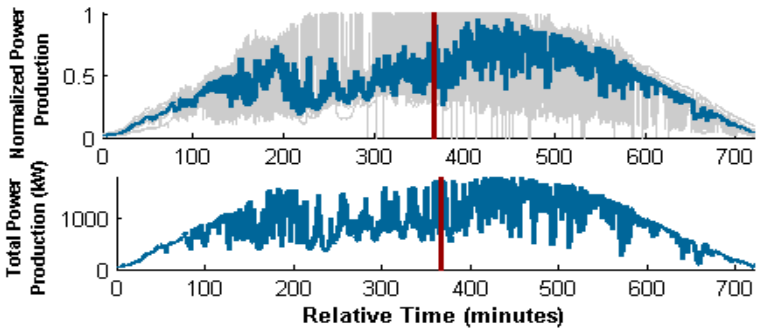
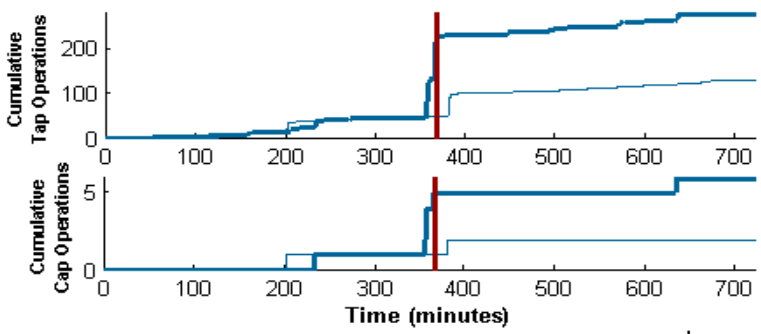
Spatial- and Time-Based Modeling









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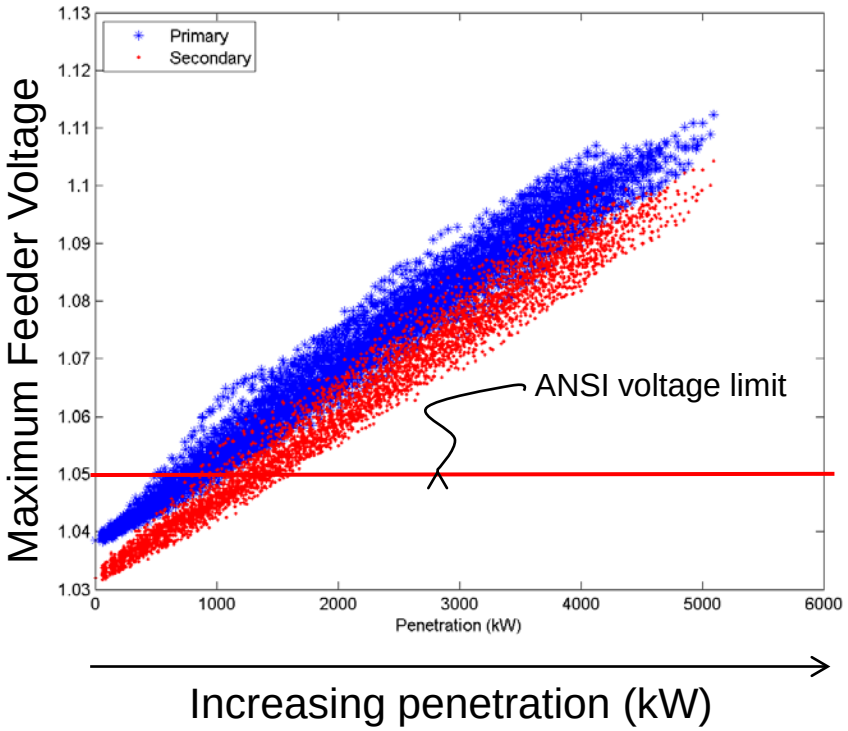
Modeling Uncertainty Regarding Future PV Deployment
Stochastic Analysis

- Can be used for determining a particular distribution feeder's hosting capacity for PV by considering large number of possible future PV deployments
- Must consider wide range of
  - potential spatial interconnections
  - PV system sizes
- *Likelihood* of a simulated PV deployment resembling the actual future deployment increases with number of cases considered

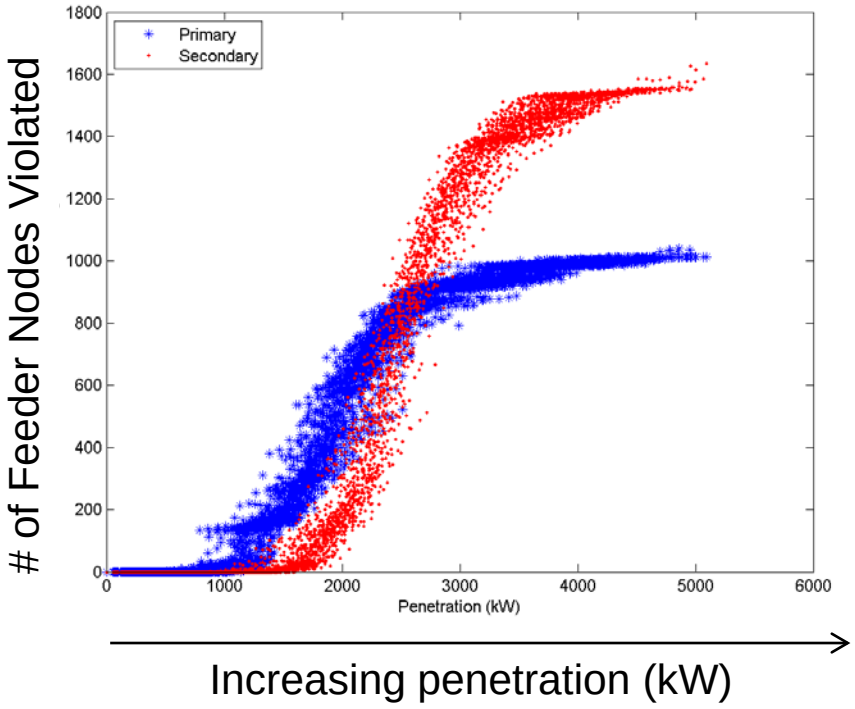
Sample Stochastic Results

Maximum Feeder Voltage

Penetration level when violations occur



Feeder exposure to violations



Blue – primary feeder voltage

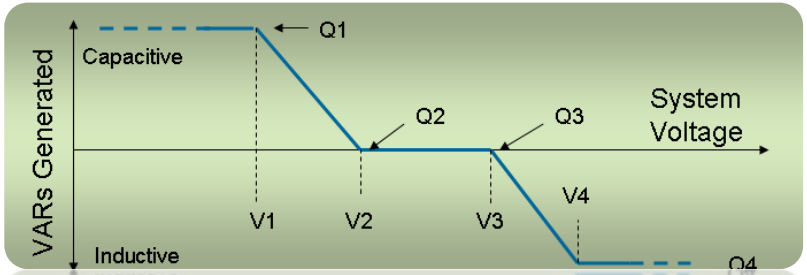
Red – secondary customer voltage

- Each point represents the worst-case voltage violation for a single PV deployment case
- 5000 cases shown

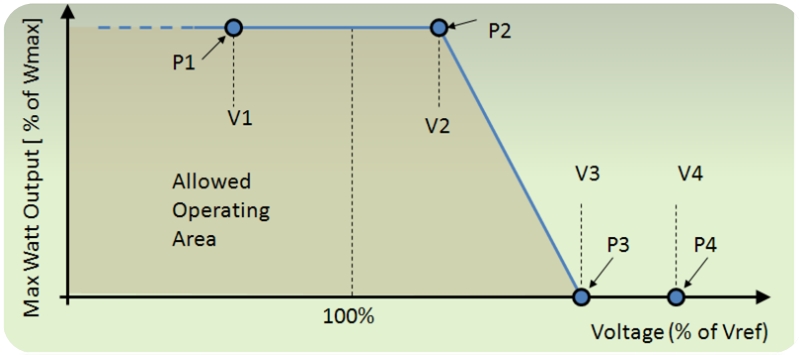
What About Evaluating Smart Inverters?

Smart inverters for providing grid support functions

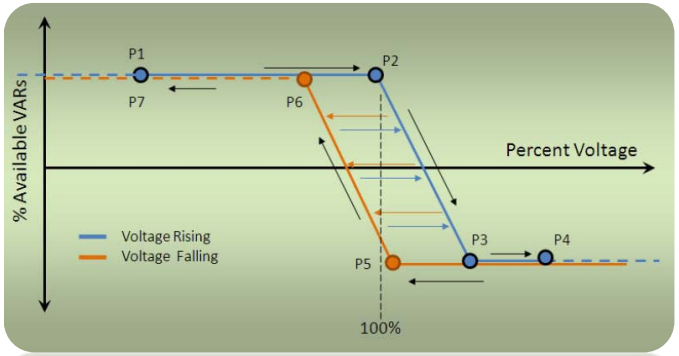
Volt-Var Control*



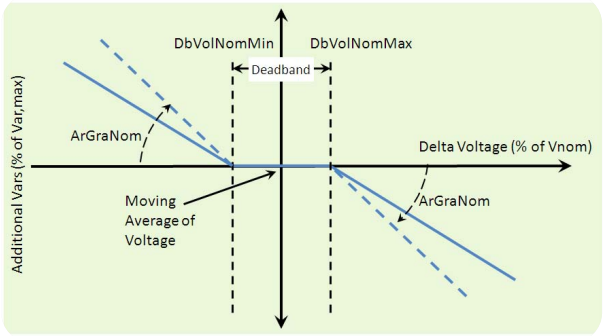
Volt-Watt Control**



Volt-Var w/ Hysteresis**



Dynamic Var Control**



*Currently in OpenDSS
**available in OpenDSS Q1 2013

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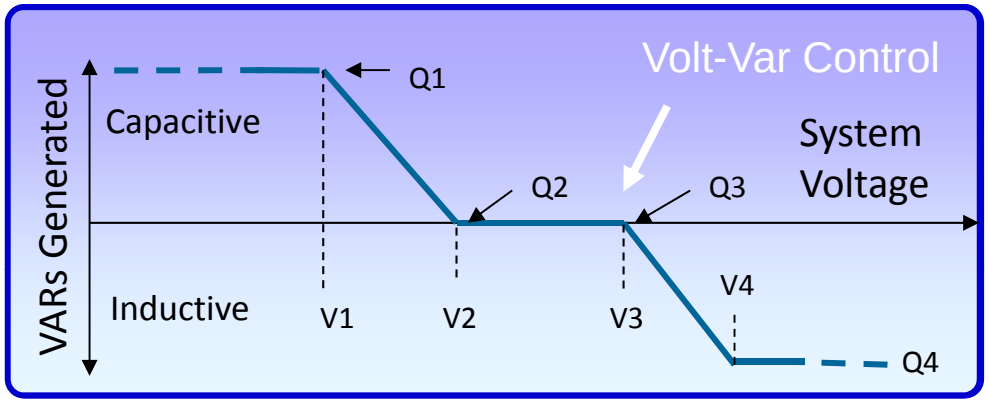
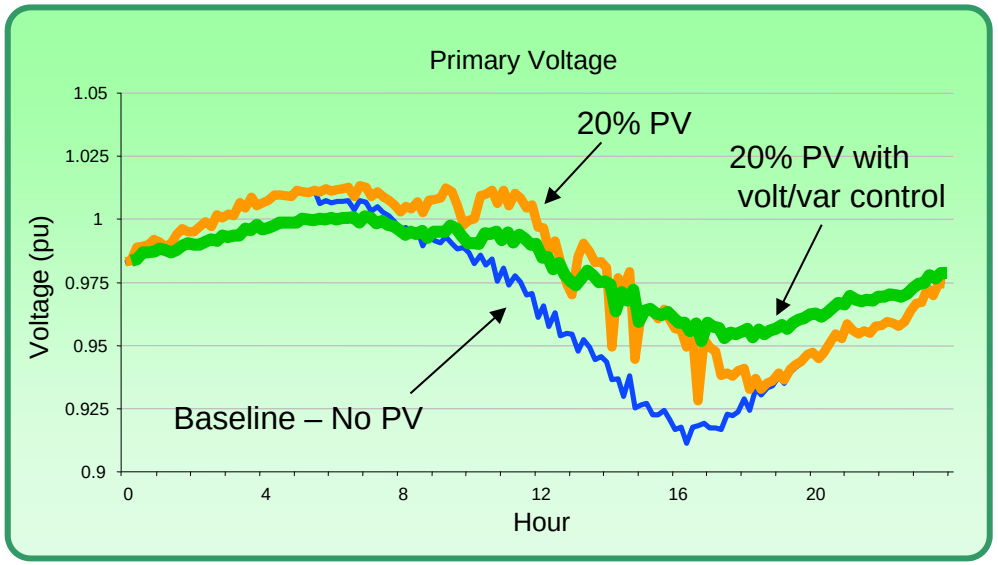
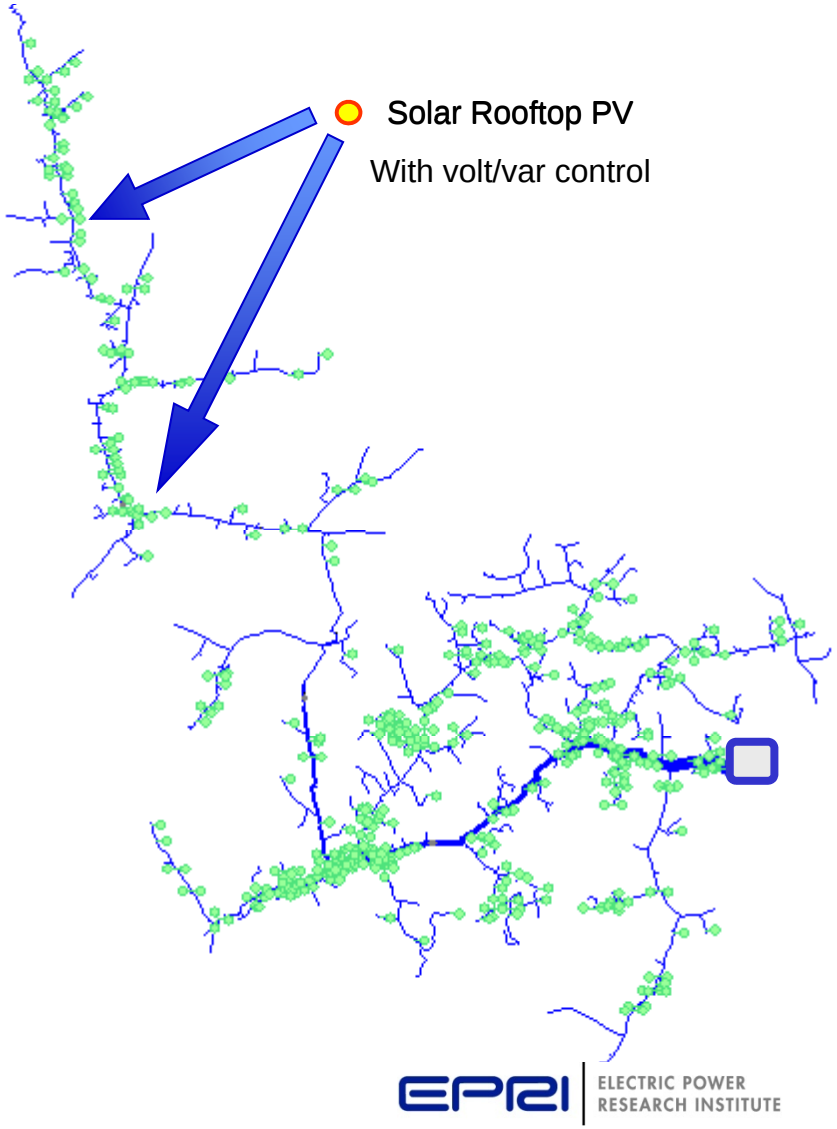
Applying PV Volt-Var Control

Mitigating Voltage Issues







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Open Discussions

Contact:

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Simulation Platform – OpenDSS

- Open source of EPRI's Distribution System Simulator
  - developed in 1997
  - open sourced in 2008 to collaborate with other research projects
- Used in 100's of distribution studies
- OpenDSS designed from the beginning to capture
  - Time-specific impacts **and**
  - Location-specific impacts
- Differentiating features
  - full multiphase model
  - numerous solution modes
  - "dynamic" power flow
  - system controls
  - flexible load models

- Needed for analysis of
  - DG/renewables
  - energy efficiency
  - PHEV/EV
  - non-typical loadshapes